Scheduling Constrained Dynamic Applications on Clusters

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joint work with

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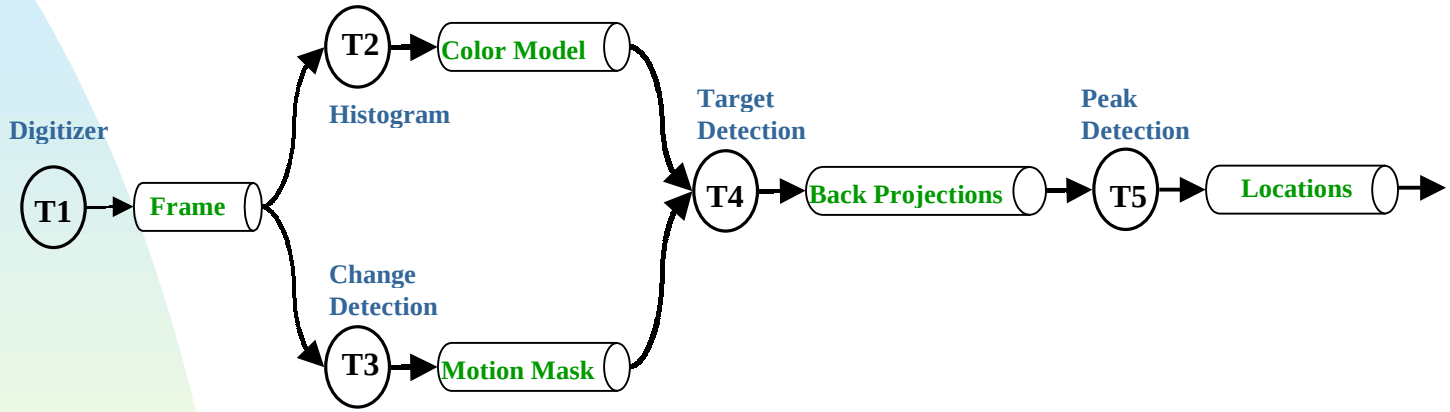
Context: user's view

- Free Standing Smart Kiosk
- Automatically detects approaching customers
- Animated face exhibits natural gaze behavior
- Interacts through synthesized voice and touch-screen

Context: programmer's view

- Multi-media applications
  - ⇒ streaming data
- Interactive
  - ⇒ response time (latency)
- Needs to be compelling
  - ⇒ natural gaze behavior (people tracking)
- Kiosk has other background apps
  - ⇒ dynamic environment

Color Tracker



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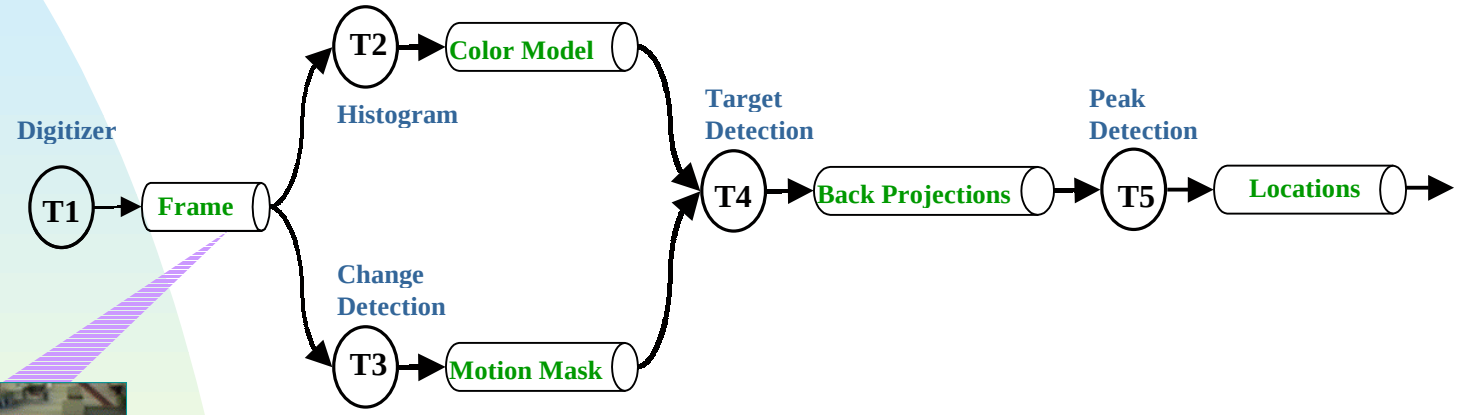

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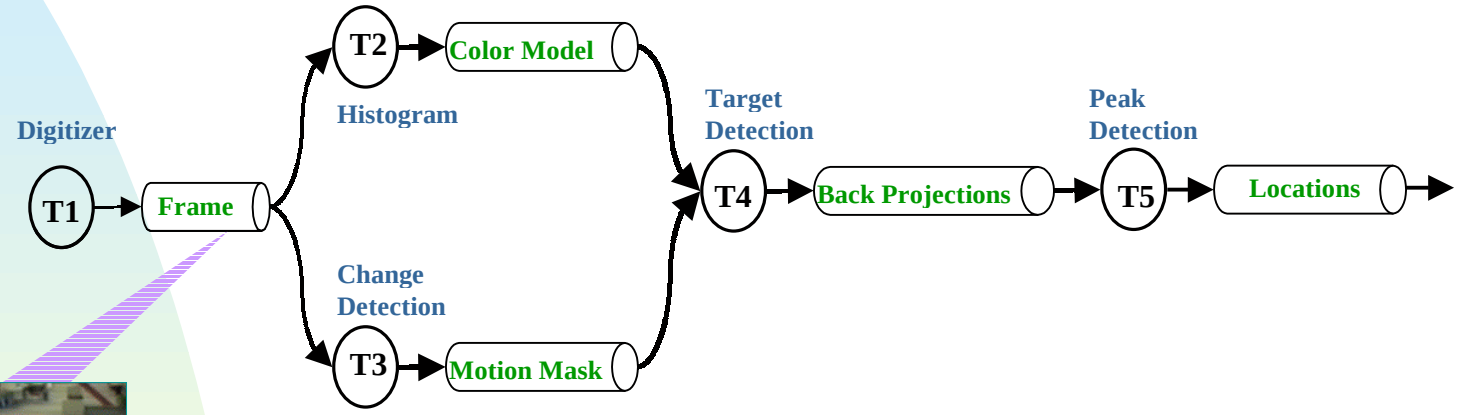

Model 1

Model 2

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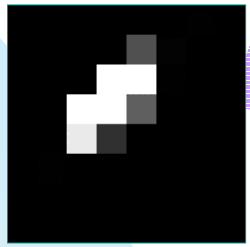

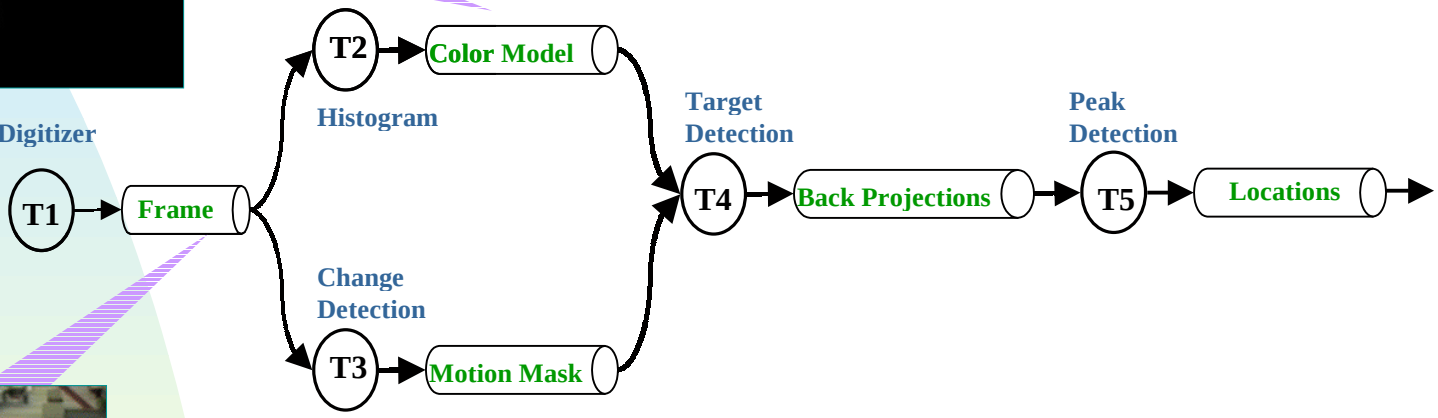

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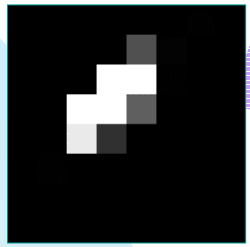

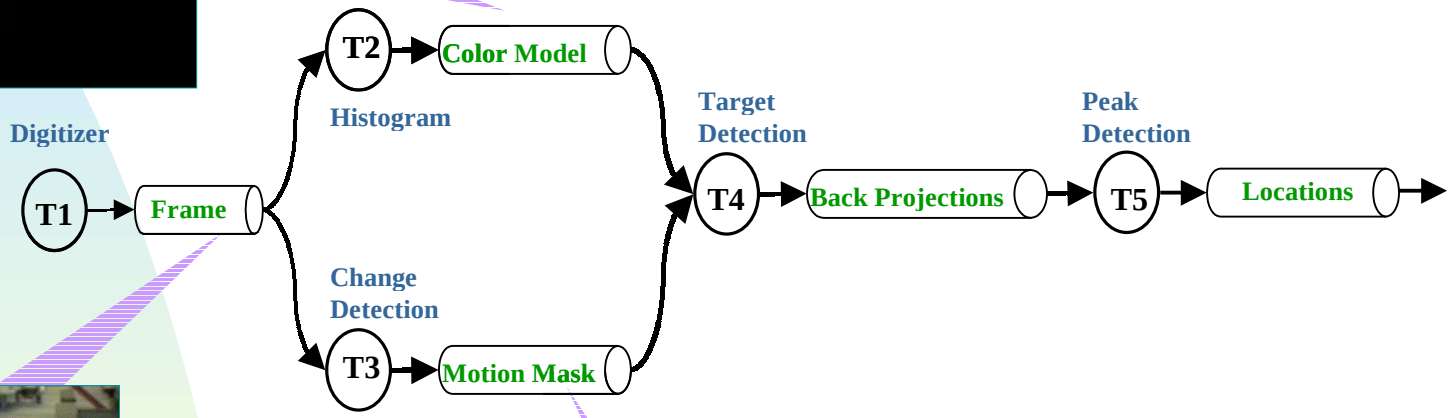

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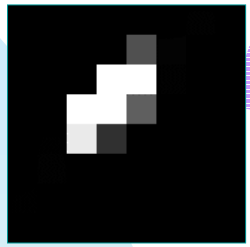

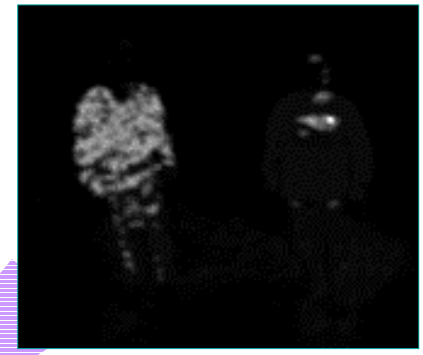

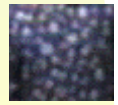

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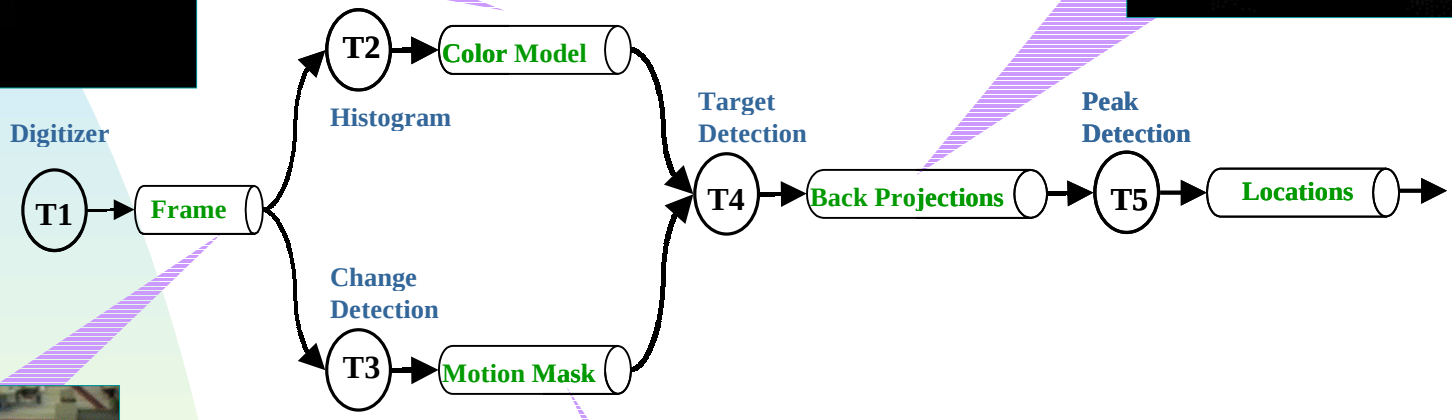

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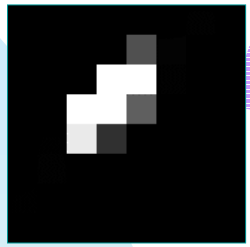

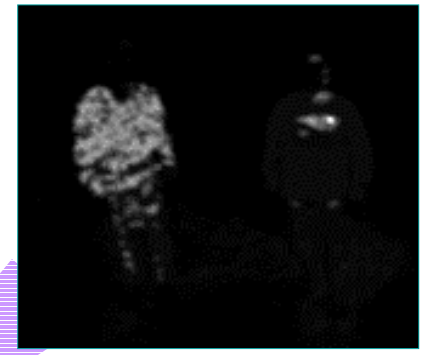

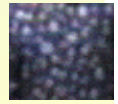

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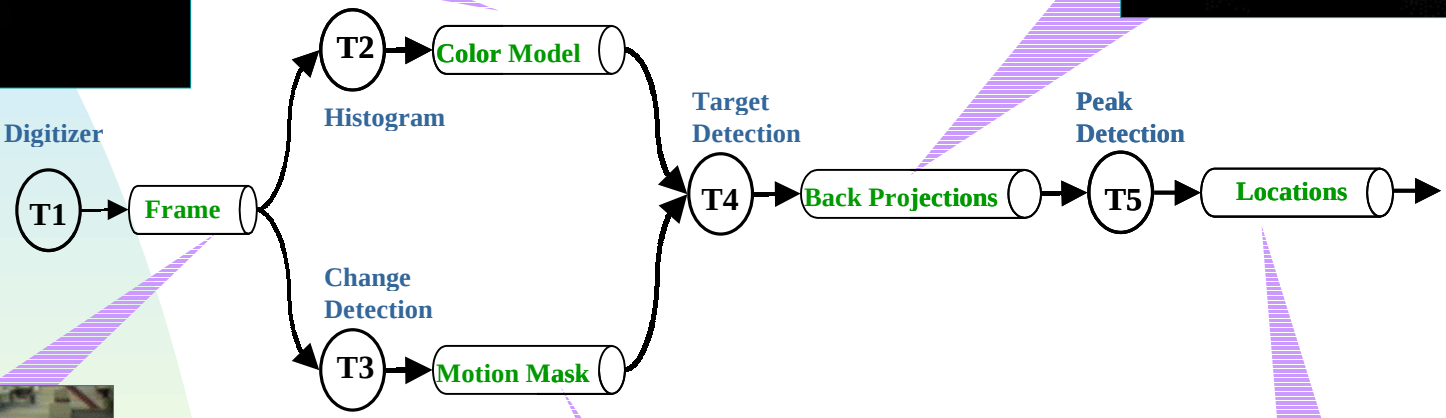
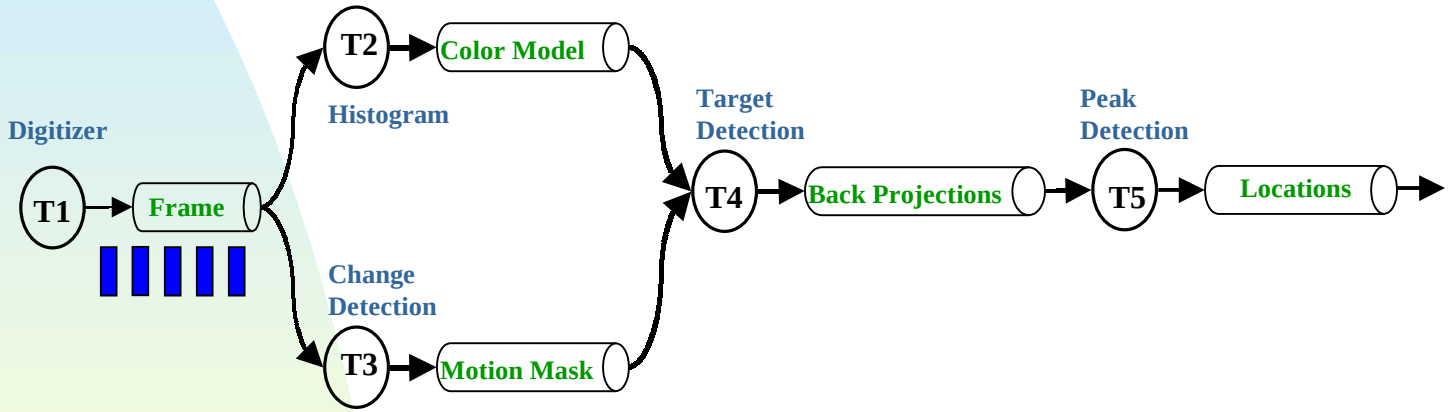


Closer Look at Tracker



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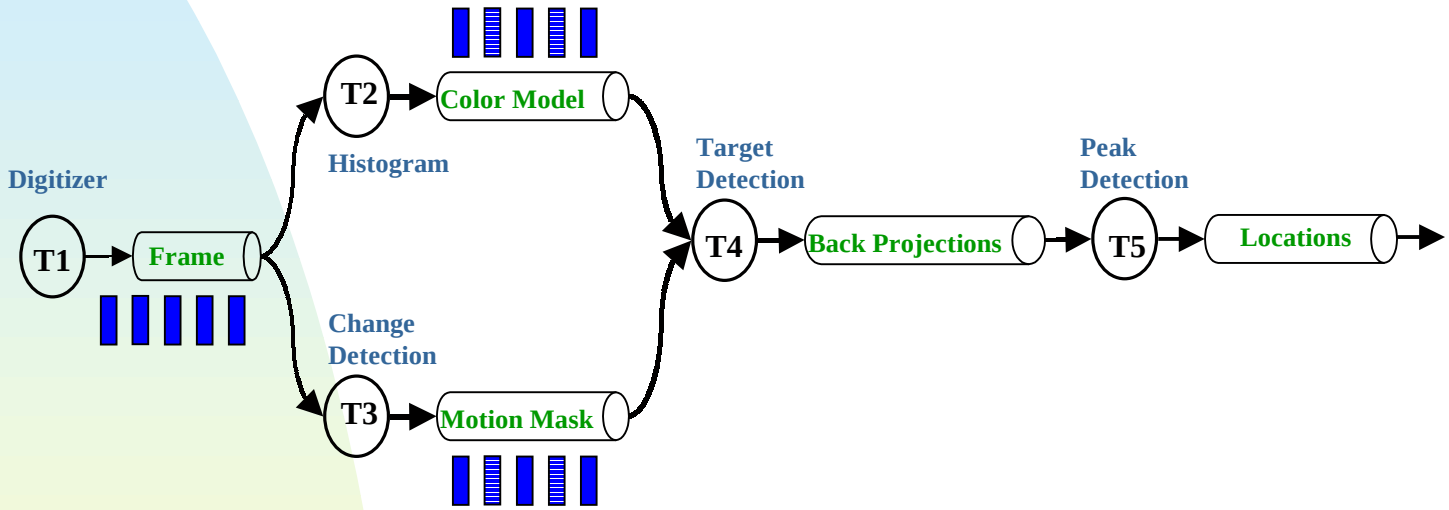

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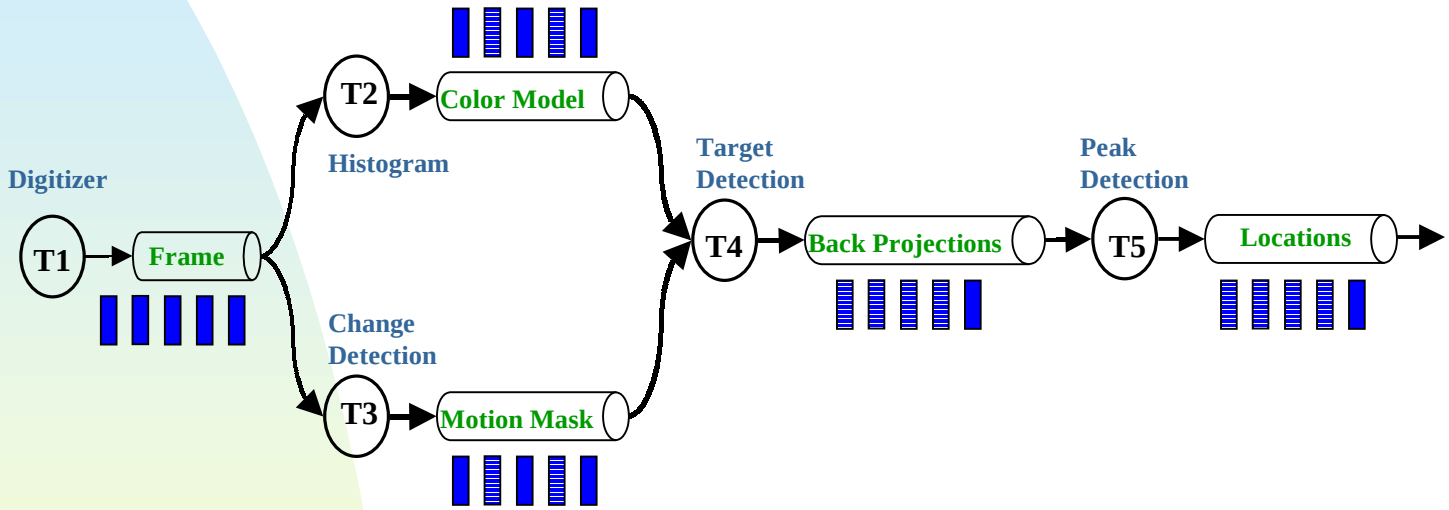

Characteristics

- Downstream tasks are more compute intensive
- Tasks “sample” the stream at varying rates
- Fundamental ability to sample at varying rates provided by Space-Time Memory

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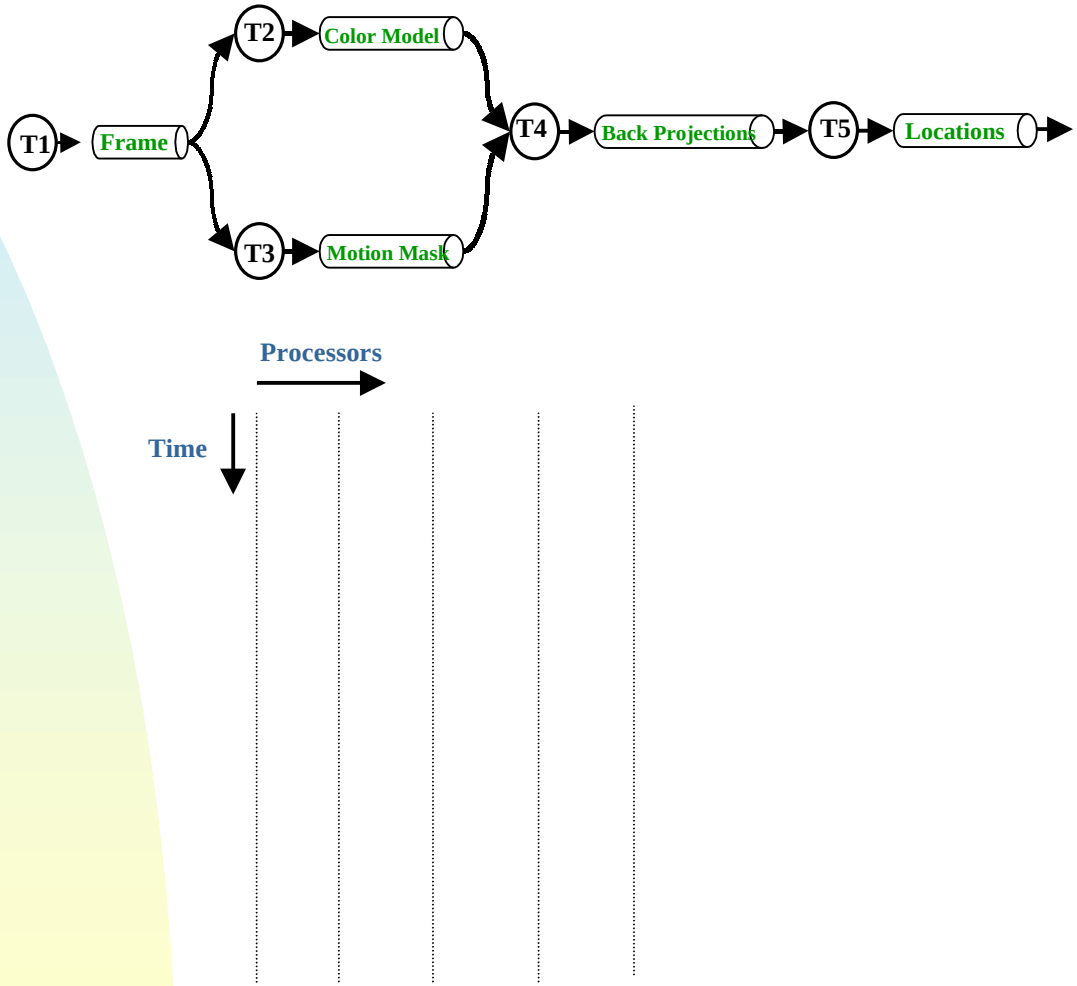
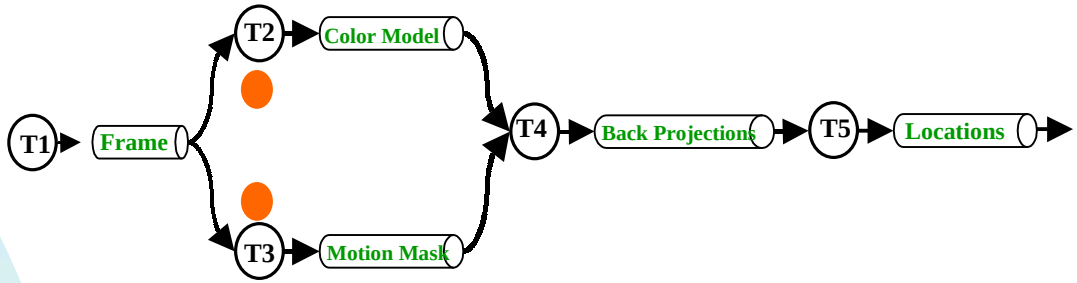
Raises scheduling questions

The Problem


T1
Frame
T2
Color Model
T3
Motion Mask
T4
Back Projections
T5
Locations
Processors
Time

The Problem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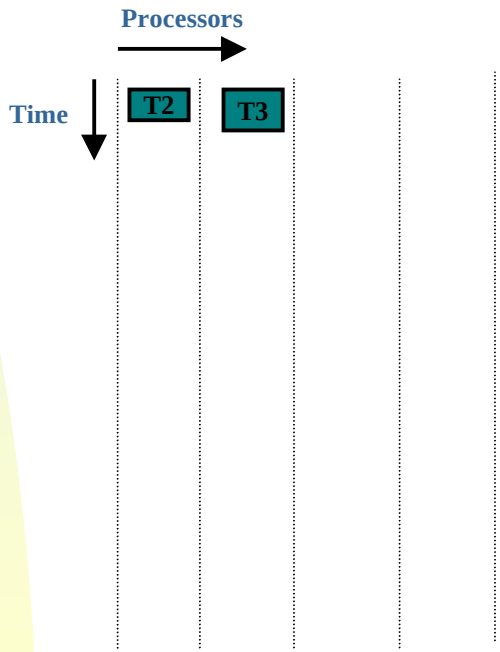
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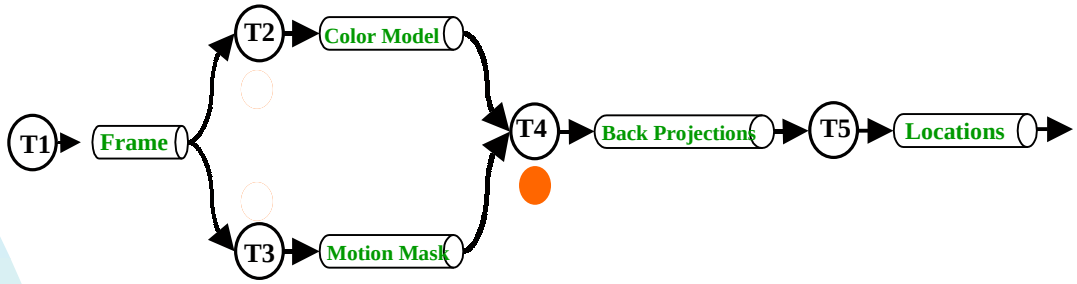
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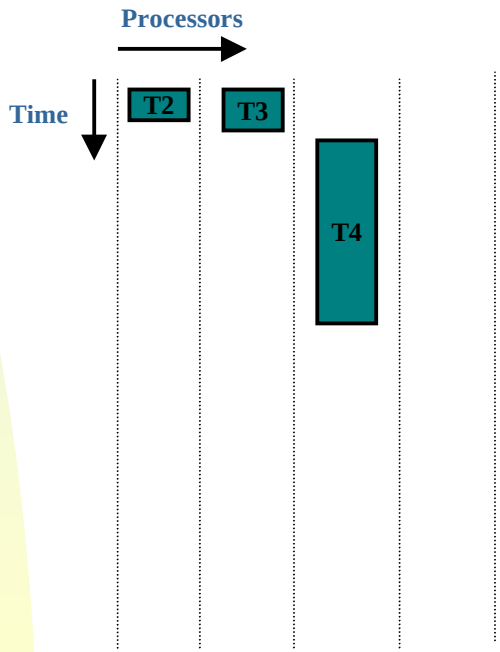
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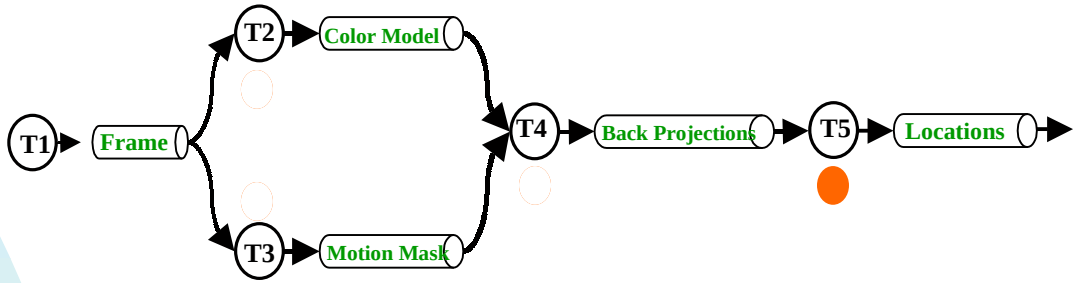
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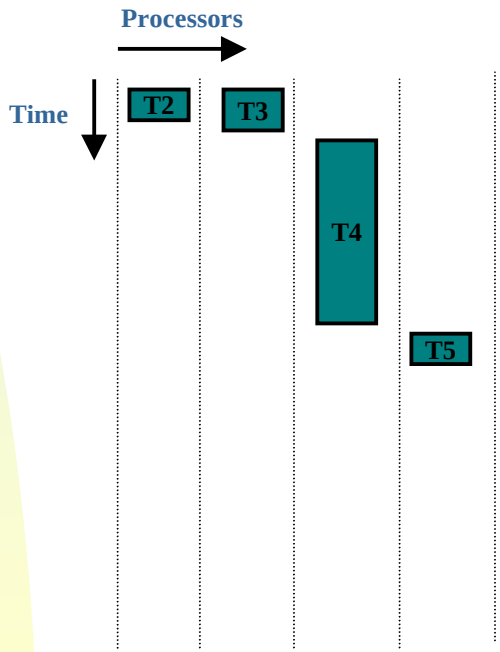
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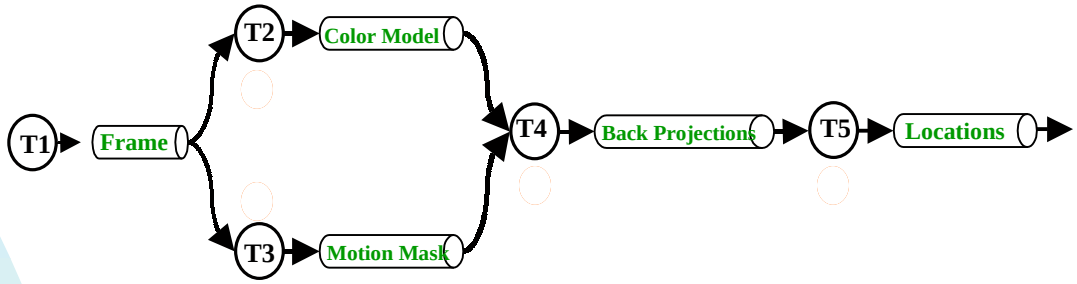
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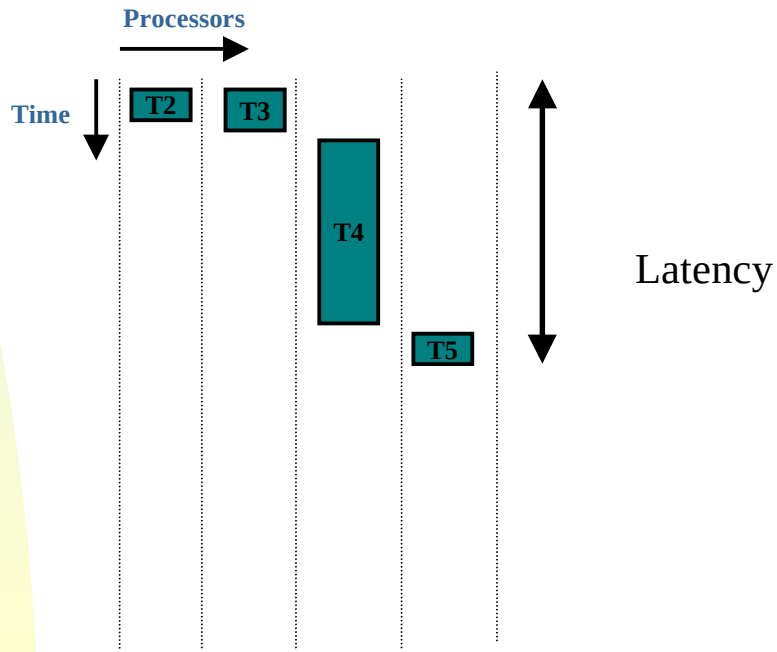
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Latency

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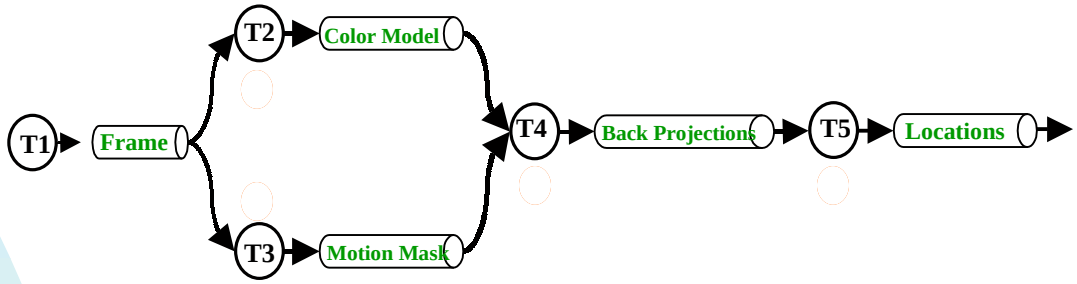
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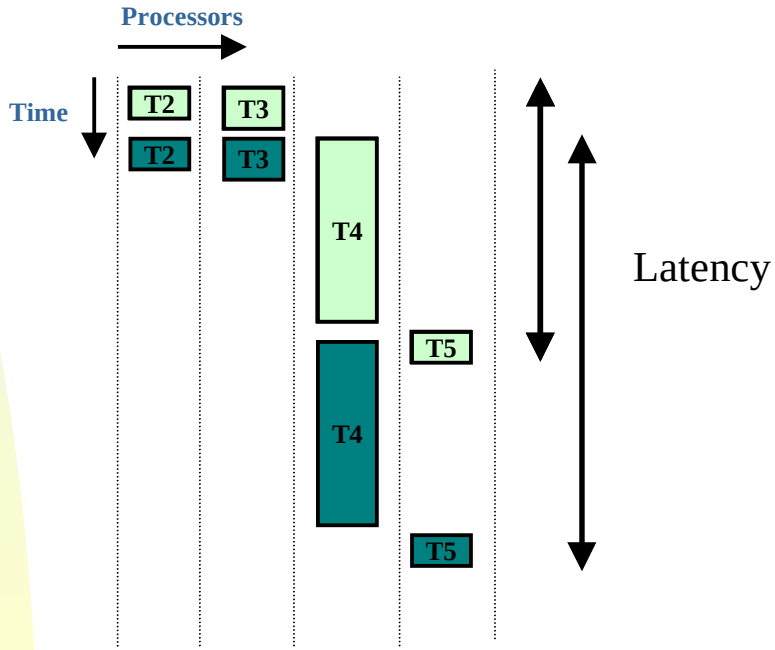
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Metrics

- Good use of resources
  - good throughput
- Kiosk must be compelling and interactive
  - low latency per frame
  - avoid “dead” periods
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Do this in a dynamic environment

Constrained Dynamism

- The system changes among a small number of states
  - run-time environment, e.g., number of processors available, or load
  - input dependent, e.g., number of users
- State changes are infrequent
- State changes are detectable

Improving the Schedules

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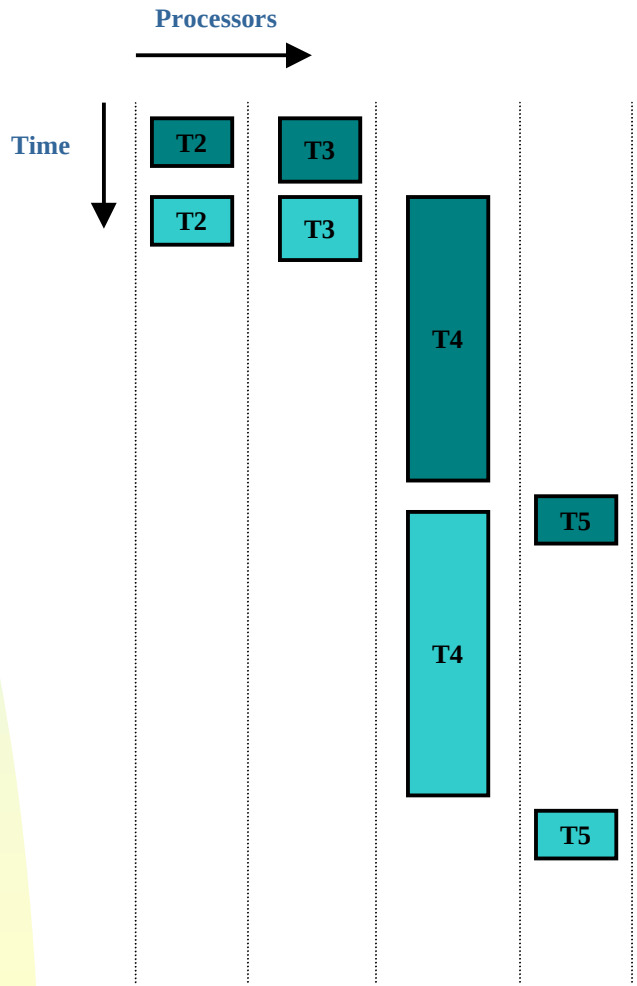

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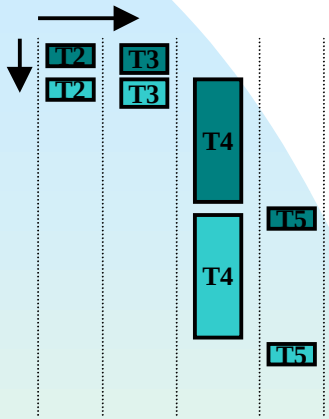

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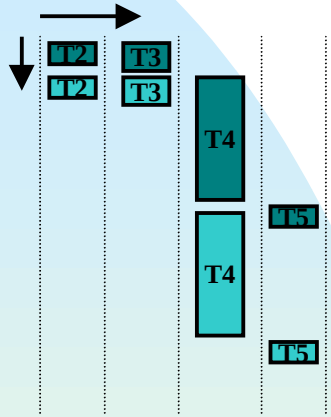

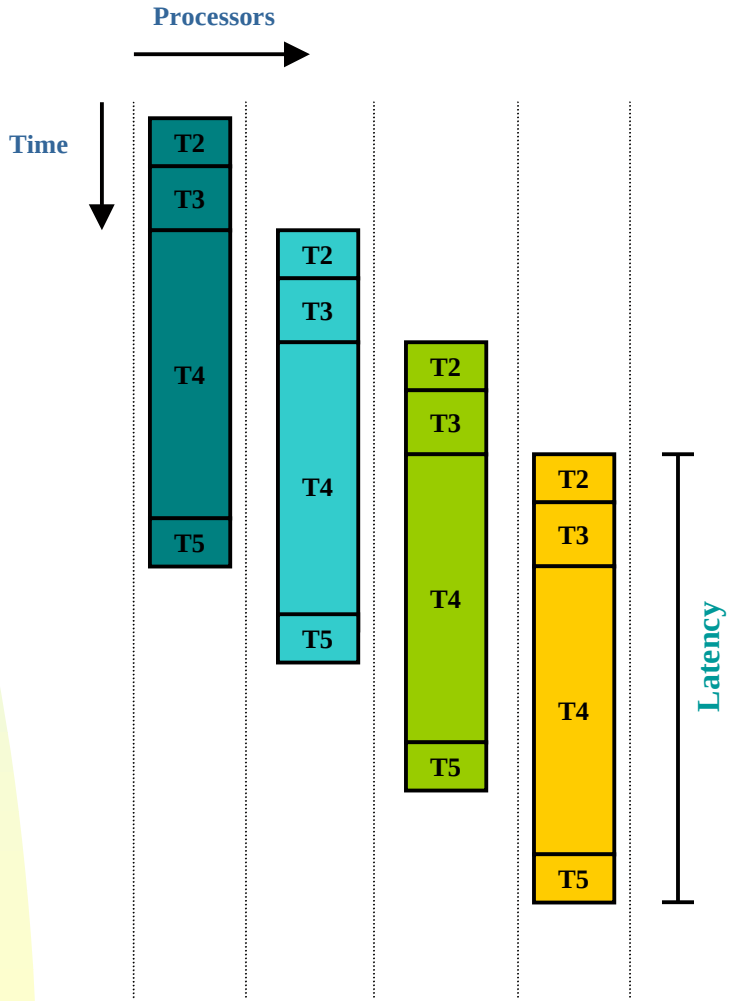

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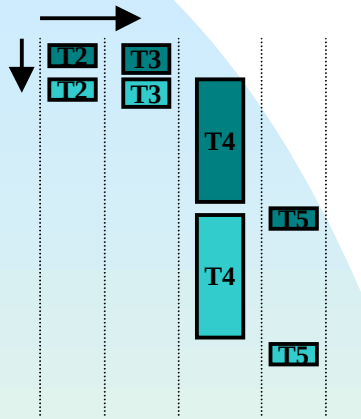

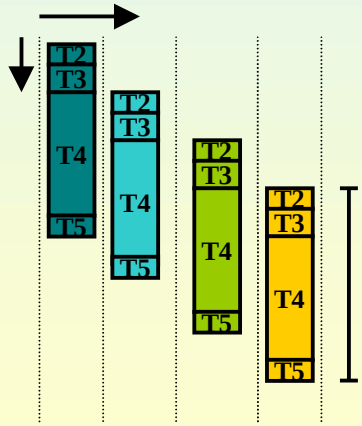

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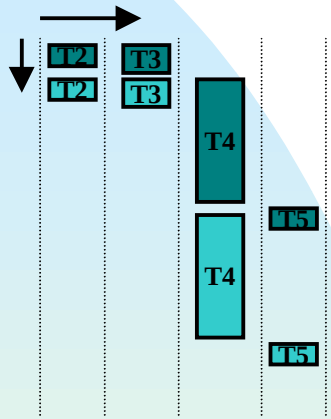

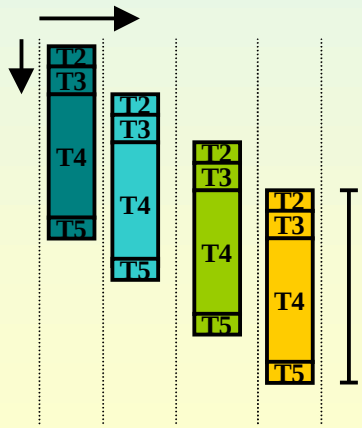

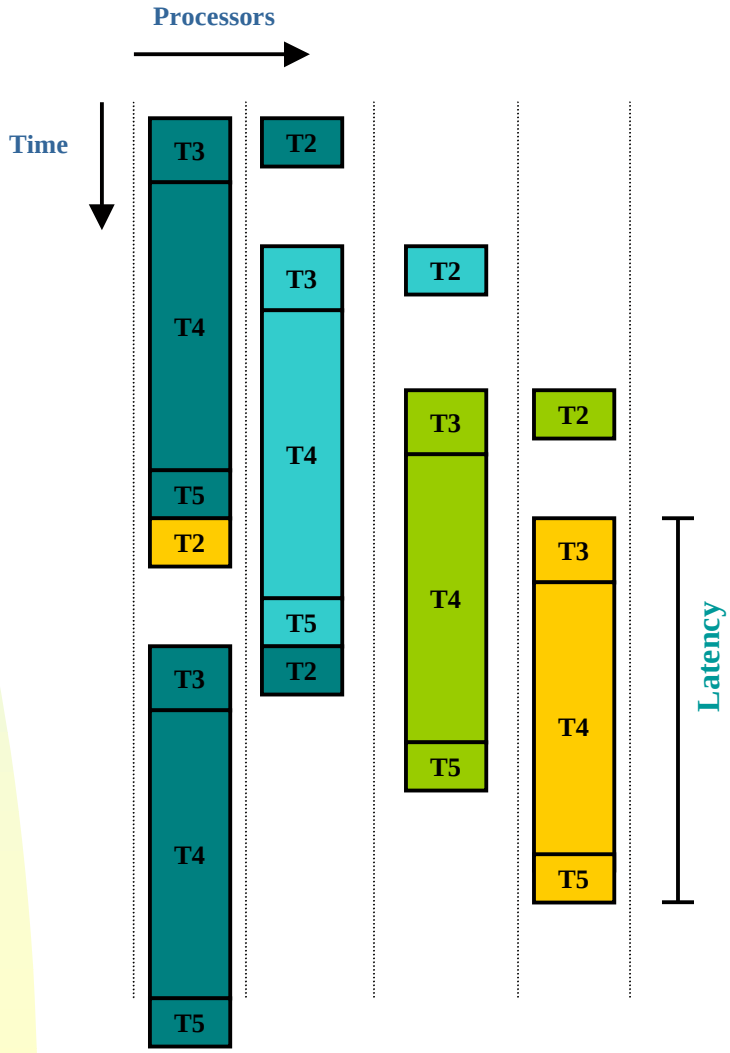

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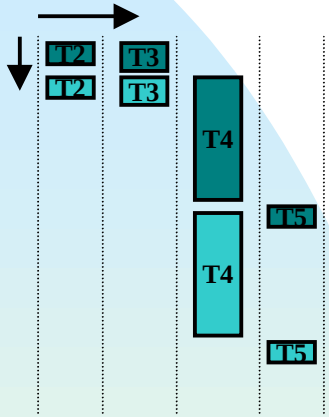

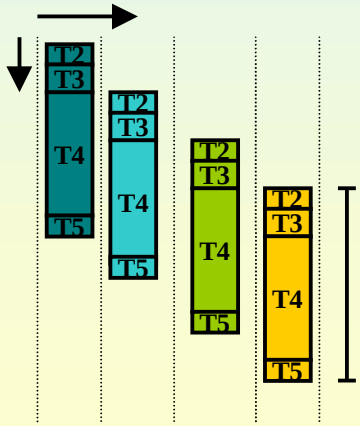

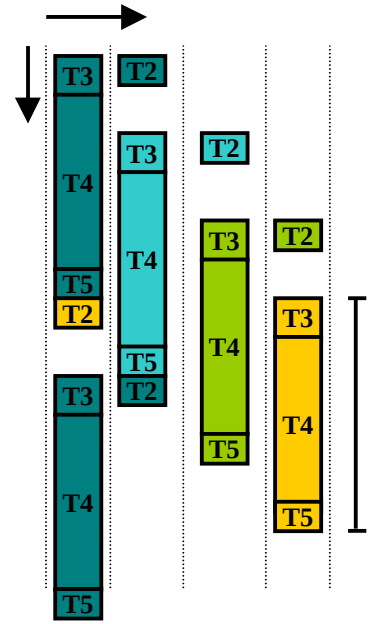

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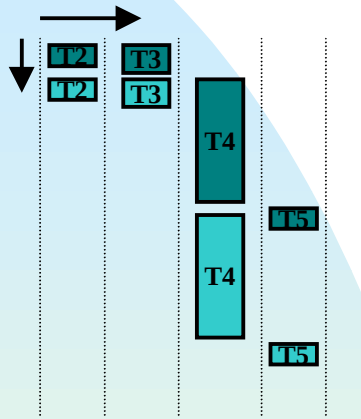
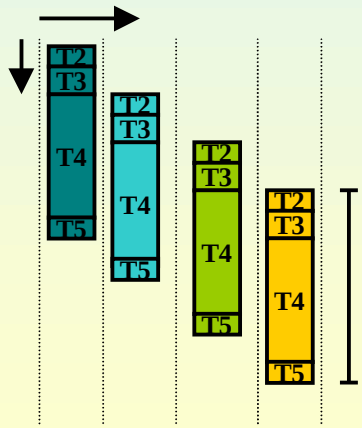
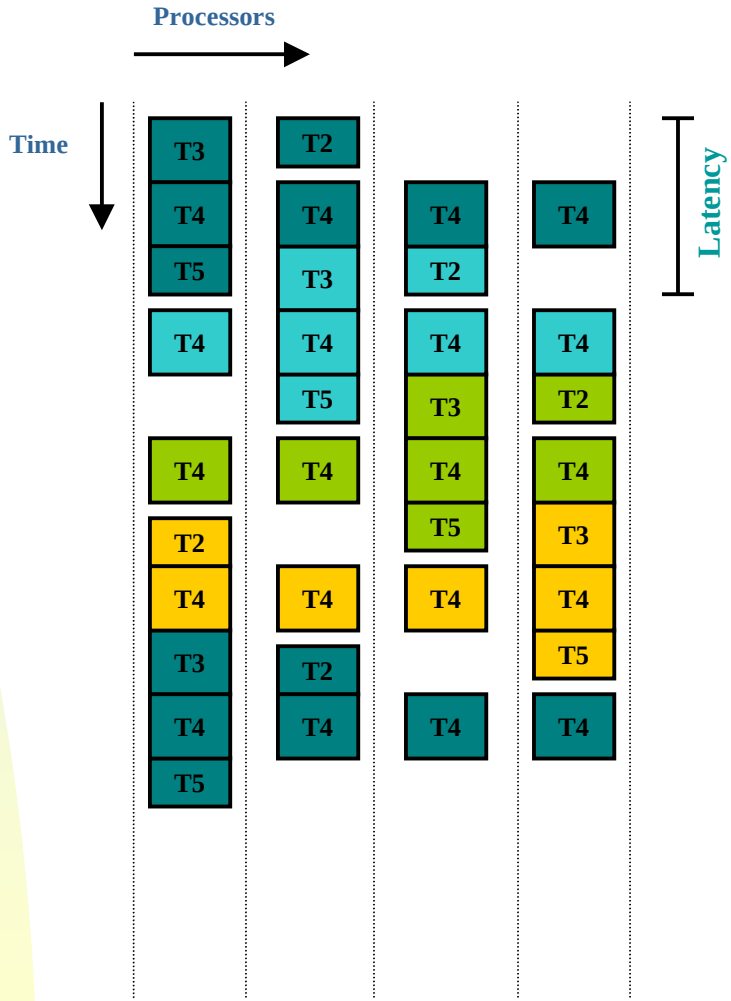
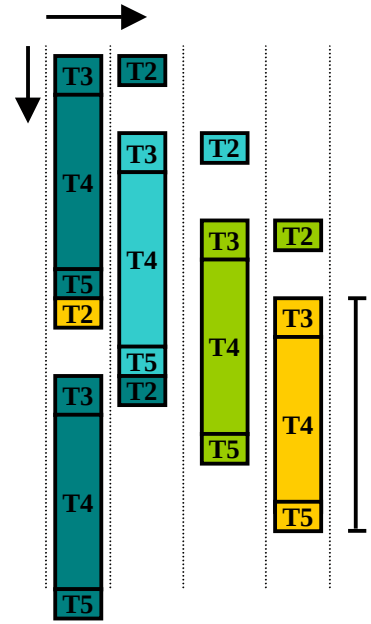






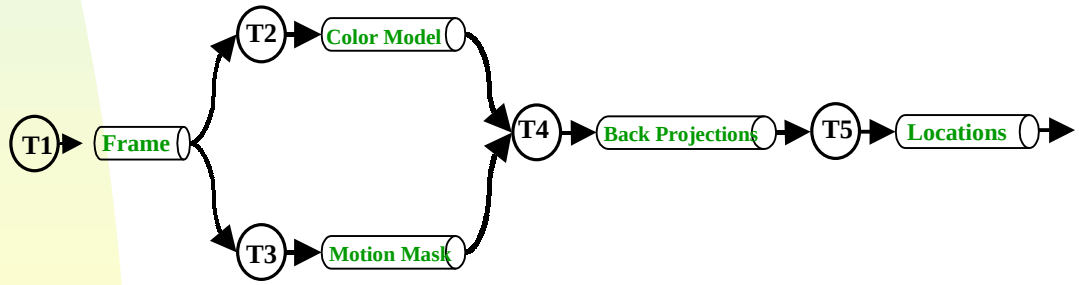


How does this work?

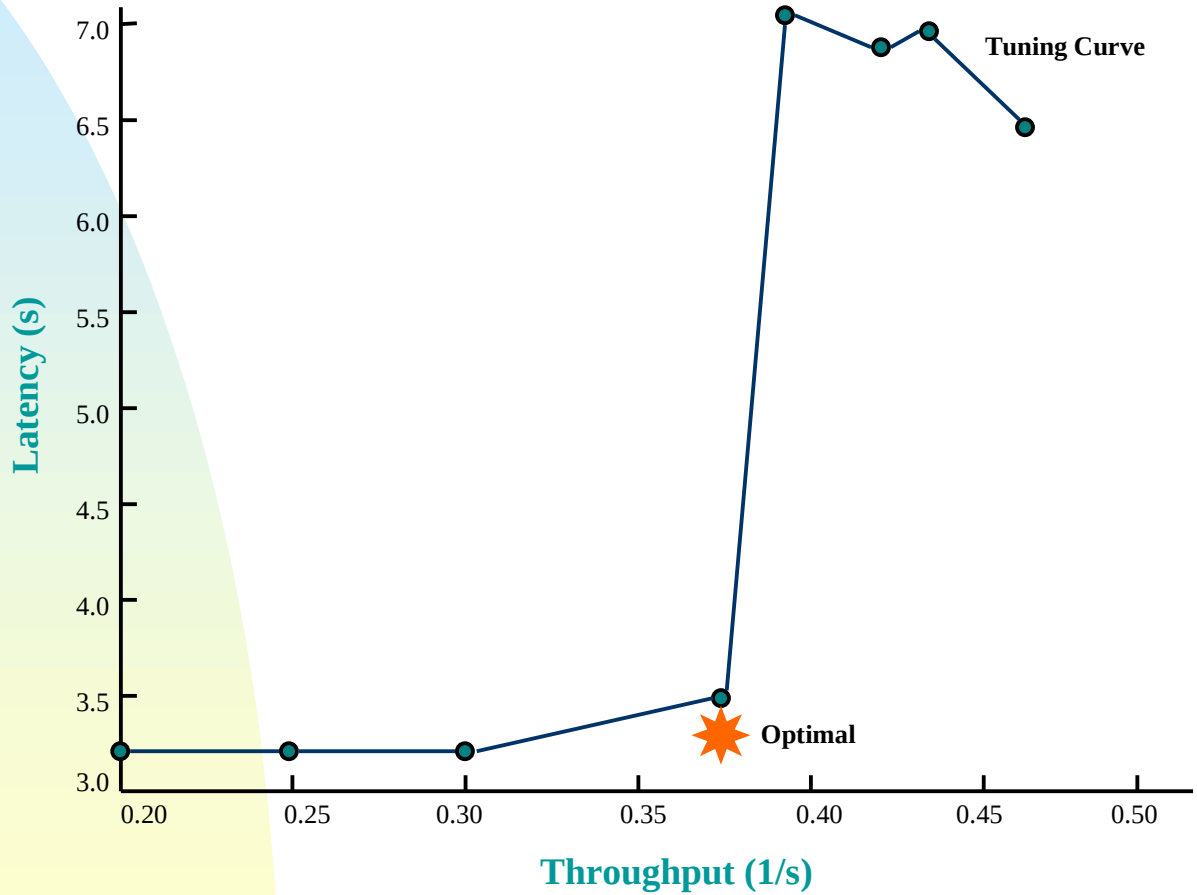
- Compute optimal schedules for each state
  - input: execution time, communication time
  - compute: minimal latency, single iteration schedule for minimal latency, and finally multiple iteration schedule
- Detect the current state at run-time and choose the best schedule

Why does this work?

- Alternatives
  - Do nothing!
  - Control rate of frame generation
  - Control the size of inter-task “channels”
- A limited number of states is the key



Comparison


7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Latency (s)
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Throughput (1/s)
Tuning Curve
Optimal

Benefits

- No extra work (good resource utilization)
- Reduces “live” time (smaller space req.)
- Simplifies garbage collection
- Implicitly solves flow control

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Works on commodity systems

Data Decomposition

	Total Models		
	1	8	
Partitions	MP=1	MP=8	MP=1
FP=1	0.876	1.857	6.850
FP=4	0.275	2.155	2.033

- Number of input models defines a state
- Small number of states $\Rightarrow$ constrained dynamism

Conclusion

- A class of applications exhibits the property of “constrained dynamism”
- The property enables state-based approach to obtain good schedules in the face of dynamic environment
- Constrained Dynamism also helps in other aspects of application tuning, like, parallelization strategy